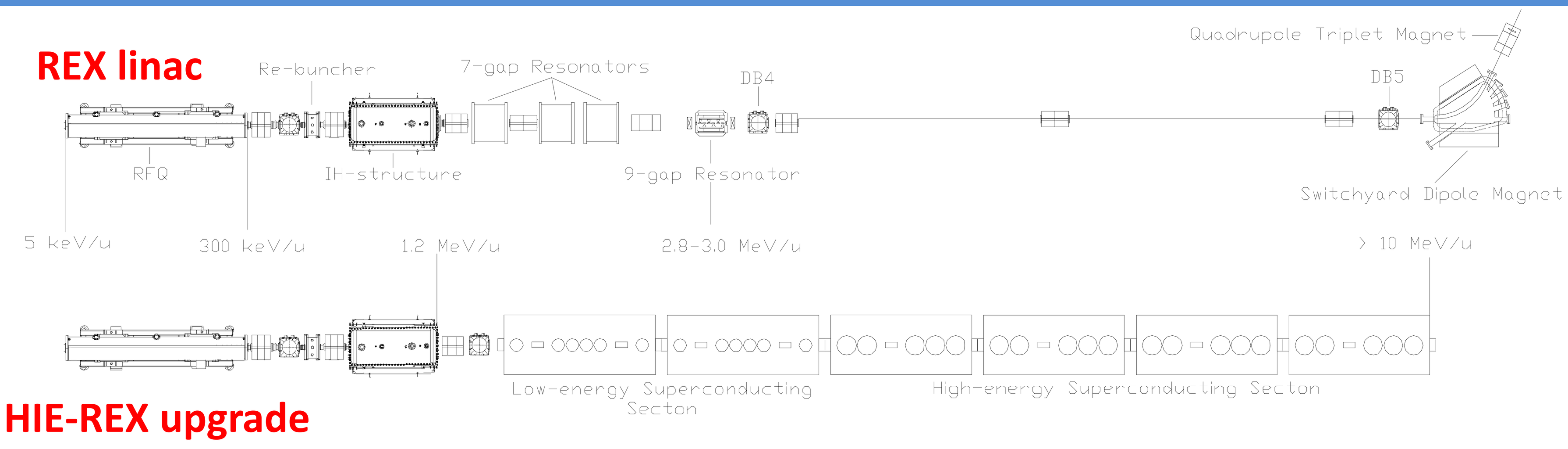
Development of a Silicon Detector Monitor for the HIE-ISOLDE linac

F. Zocca[1,2], M.A. Fraser[2,3], E. Bravin[2], M. Pasini[2,4], D. Voulot[2], F. Wenander[2]

[1]Instituto de Estructura de la Materia - CSIC, Madrid, Spain; [2]CERN, Geneve, Switzerland
[3]Cockcroft Institute, Warrington and University of Manchester, UK; [4]Instituut voor Kern-en Stralingsfysica, Leuven, Belgium

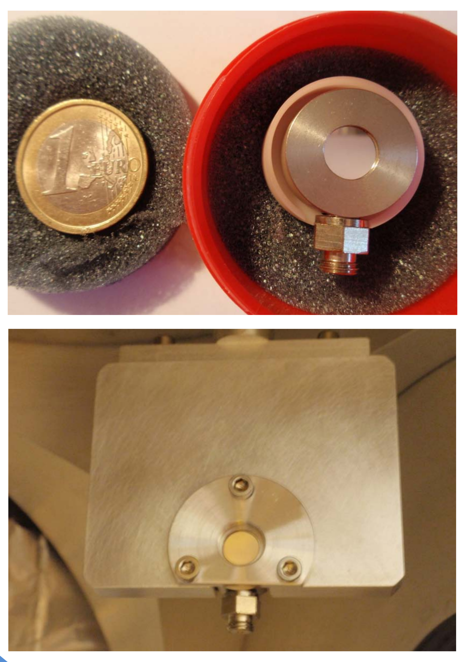
HIE-ISOLDE project

The High Intensity and Energy ISOLDE (HIE-ISOLDE) project is a major upgrade of the existing ISOLDE and REX facilities with the objective of increasing the energy and the intensity of the delivered radioactive ion beam (RIB). This project aims to fill the request for more energetic post accelerated beams by means of a new superconducting (SC) linac based on Quarter Wave Resonators (QWRs). A research and development program looking at all different aspects of the SC linac has started in 2008, including cavity prototyping and testing, cryomodule design, beam dynamics and beam diagnostics.



Silicon Detector Monitor

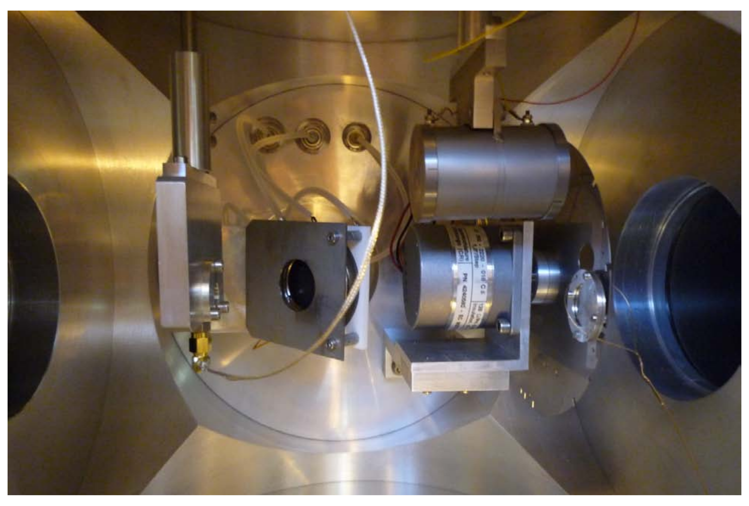
A silicon detector monitor is being developed for beam energy and timing measurements mostly aimed at phase scanning of the superconducting cavities. Tests have been performed with a stable ion beam, composed of carbon, oxygen and neon ions accelerated to energies from 300 keV/u to 2.85 MeV/u. The silicon detector has been placed directly in the beam and tested with a strongly attenuated beam to simulate the single particle detection regime for which the monitor is intended to finally function.



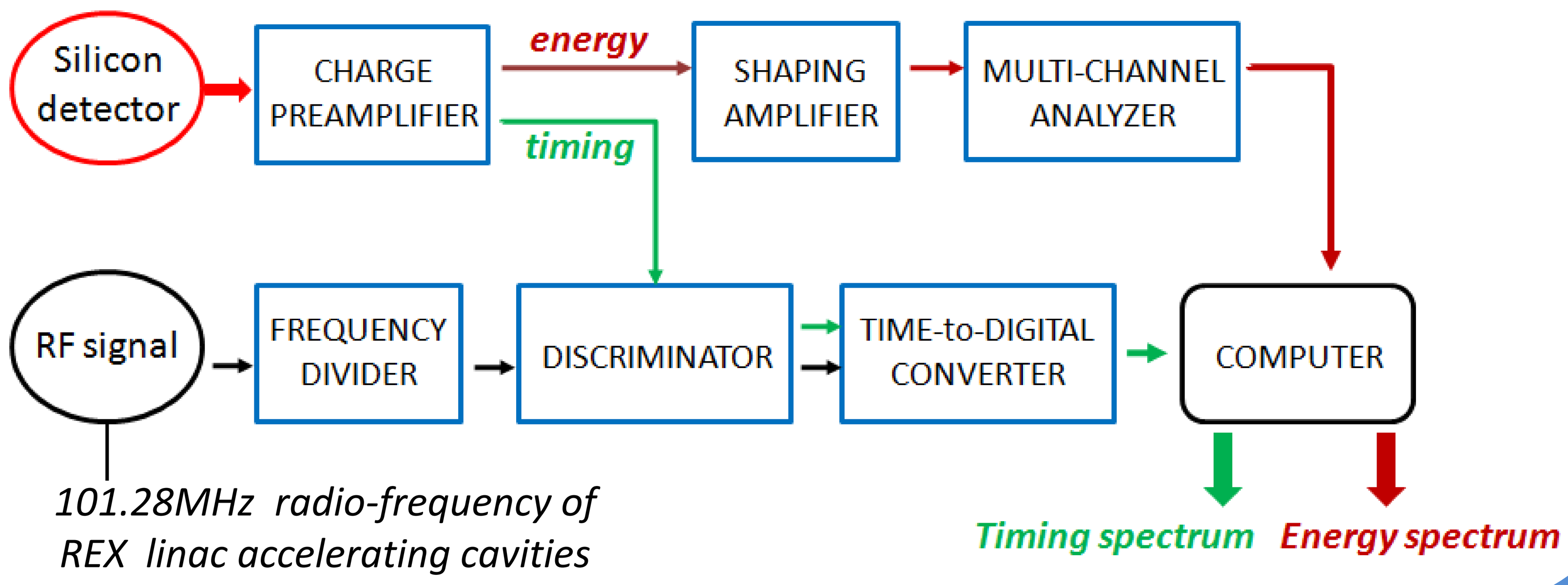
Passivated Implanted Planar Silicon (PIPS) detector

- Area= 50mm² (active diameter = 8 mm)
- Thickness = 300 μm
- Entrance window thickness= 100 nm
- Bias voltage = +60 V (recommended)
- Leakage current (20°C) = 4nA
- Capacitance = 29 pF
- Electronic noise (20°C) = 5.8 keV (FWHM)
- Alpha resolution (20°C) = 14.3 keV (FWHM) for ^{241}Am 5486 keV aphas, at τ=0.5μs
- Estimated timing resolution < 140 ps

Test setup inside a REX diagnostic box

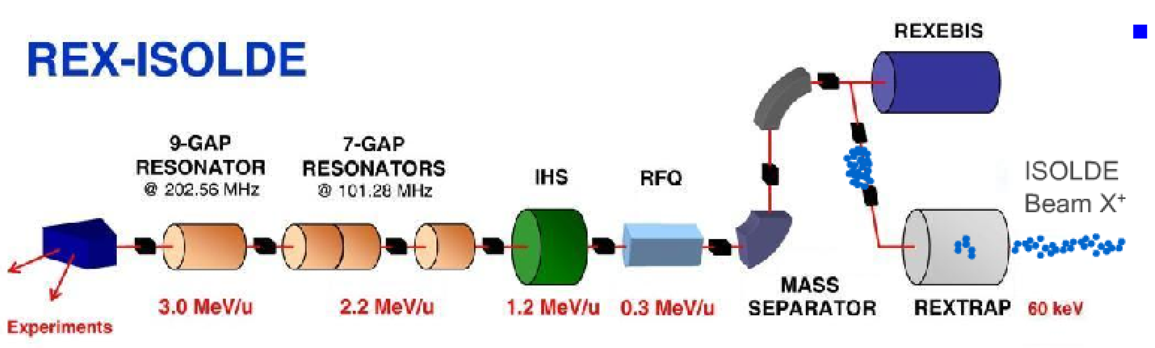


Monitor Electronics & Data Acquisition SETUP



101.28MHz radio-frequency of REX linac accelerating cavities

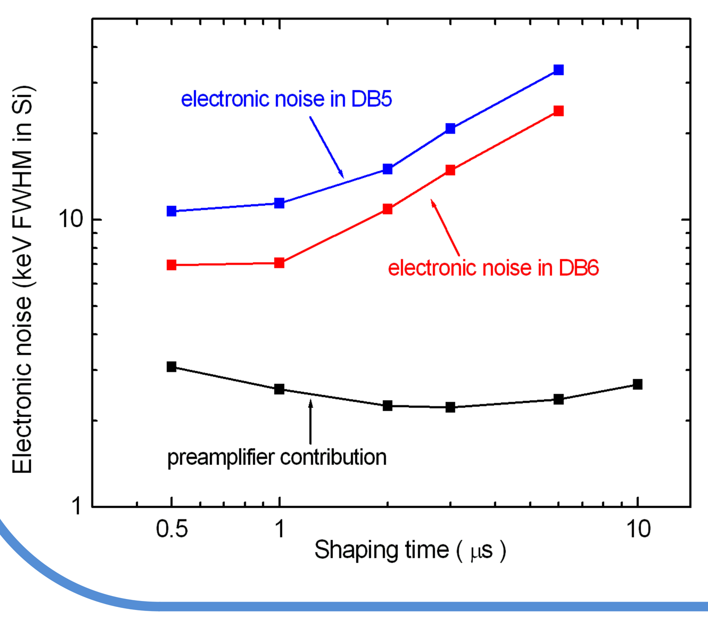
Energy Profile Measurements



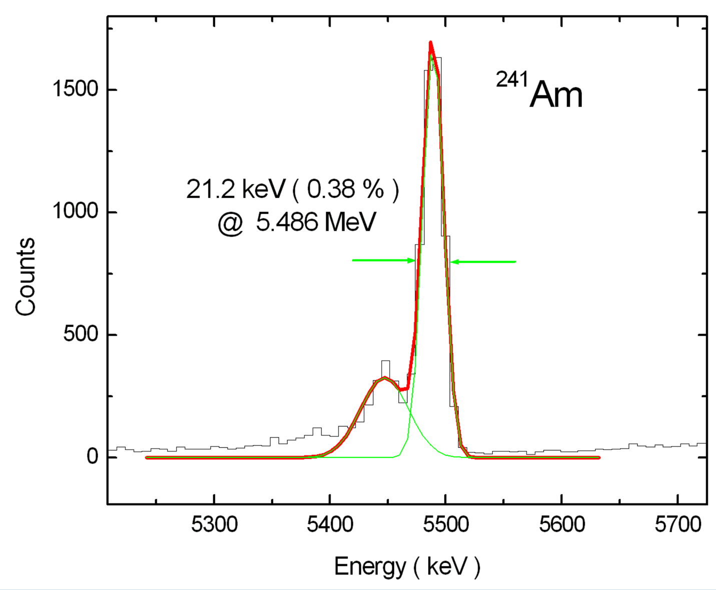
- *Stable test beam with A/Q=4 (typical): $^{12}C^{3+}$, $^{16}O^{4+}$, $^{20}Ne^{5+}$, $^{36}Ar^{9+}$ ...*
- *PULSED beam structure: repetition rate of 50Hz max. (20ms min. cooling time), pulse length typically from 50μs to 450μs*

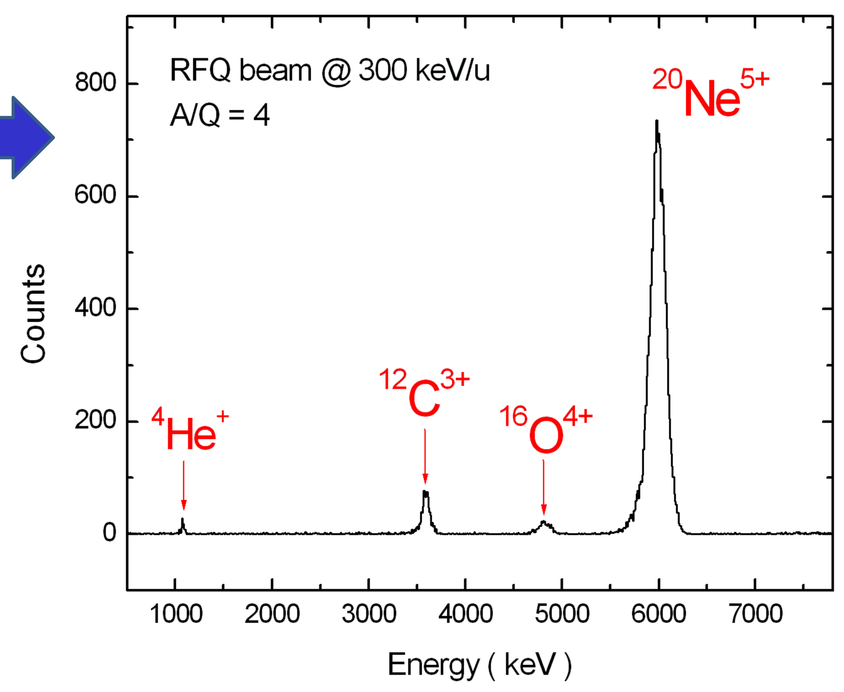
BEAM ENERGY SPECTRUM at 300 keV/u and A/Q=4. The average particle count rate is 100 Hz, corresponding to a count rate of 6.7 kHz in the RF pulse window (EBIS repetition rate of 33 Hz). **Carbon, oxygen and neon peaks are well identified**, with an energy spread of 190 keV (3.2 %) FWHM for the oxygen peak at 6 MeV. Assuming an expected beam spread contribution of 1.9 % FWHM out of the RFQ, the system energy resolution is then estimated of 2.6 % FWHM.

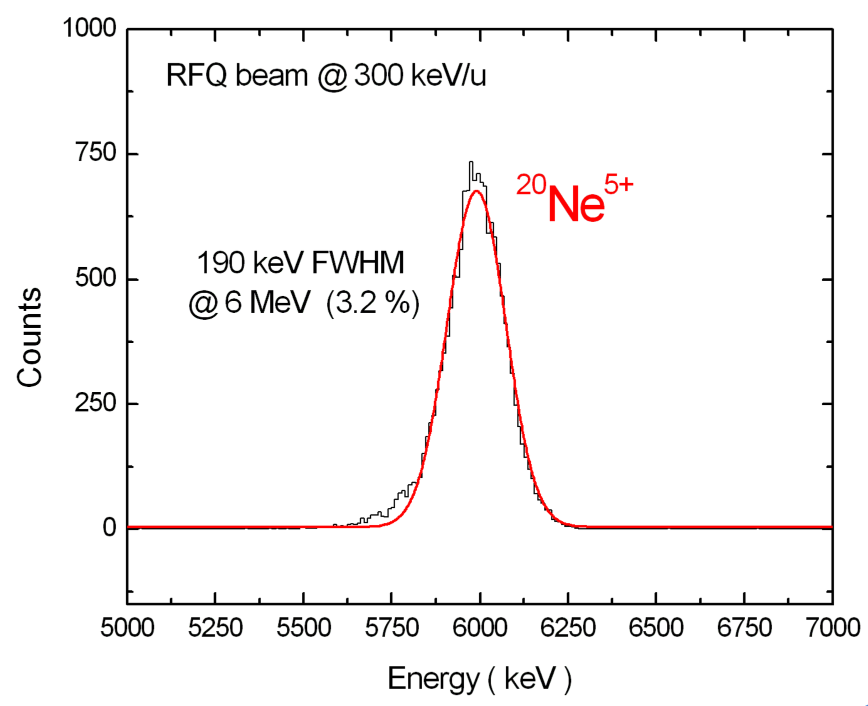
ELECTRONIC NOISE vs. SHAPING TIME



ALPHA SOURCE ACQUIRED SPECTRUM



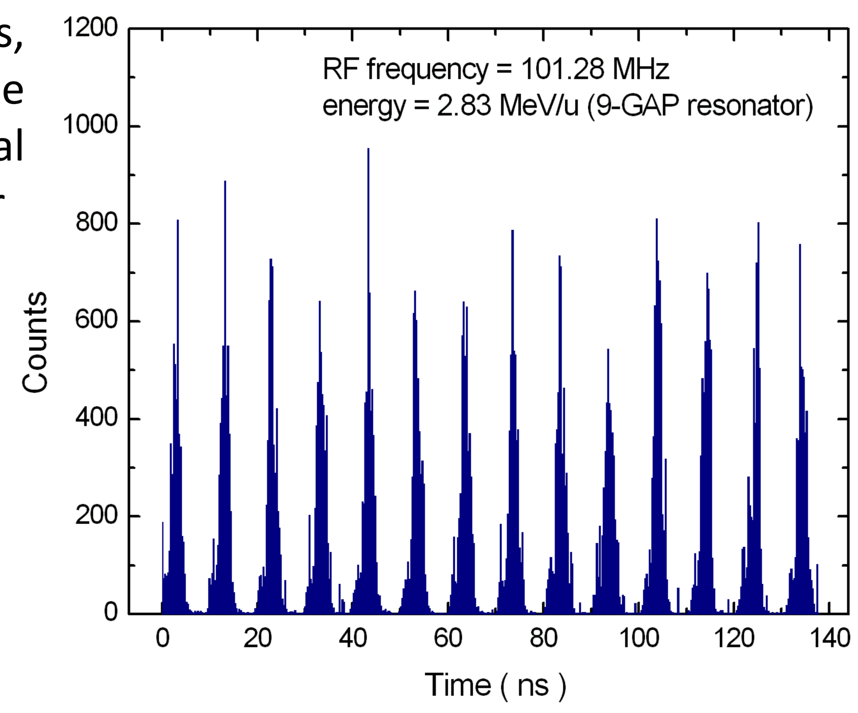


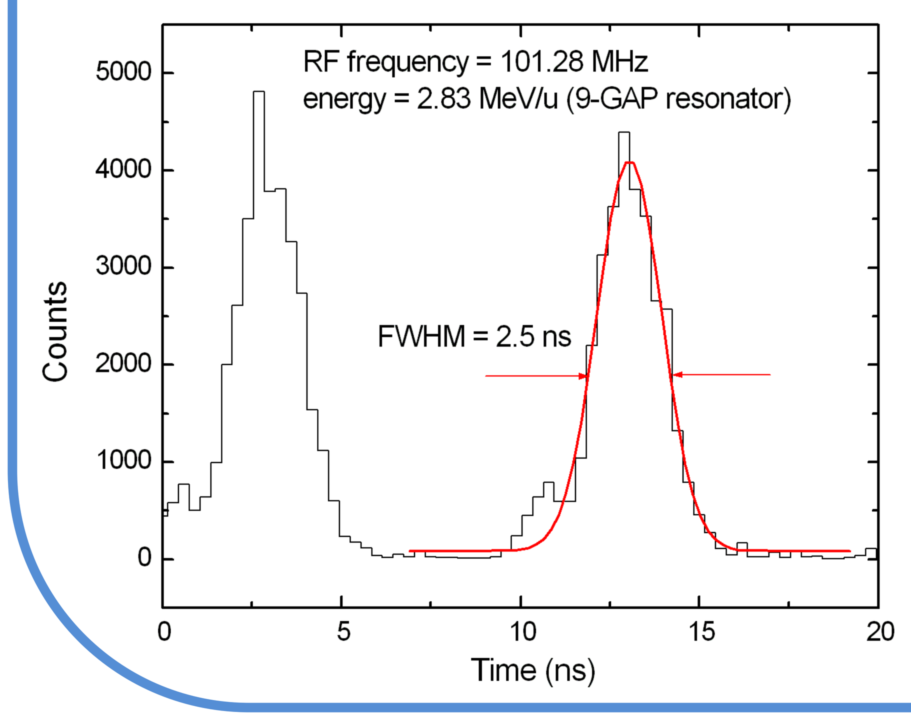


Timing Profile Measurements

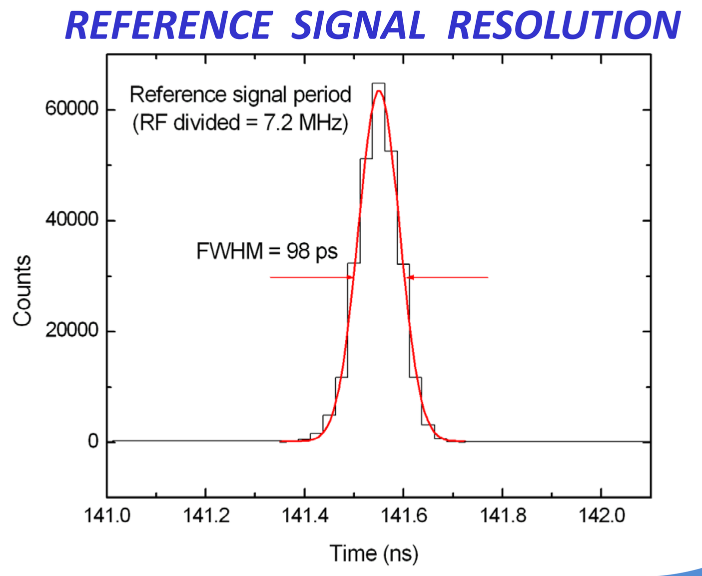
The acquired time profile shows 14 bunches, with the expected period of 9.87 ns, given the adopted reference signal was the RF signal as processed by a 14-factor frequency divider

The measured bunch length of 2.5 ns FWHM is compatible with the time spread expected at the output of the 9-GAP resonator after a drift of about 9 m to the silicon detector in diagnostic box DB6.



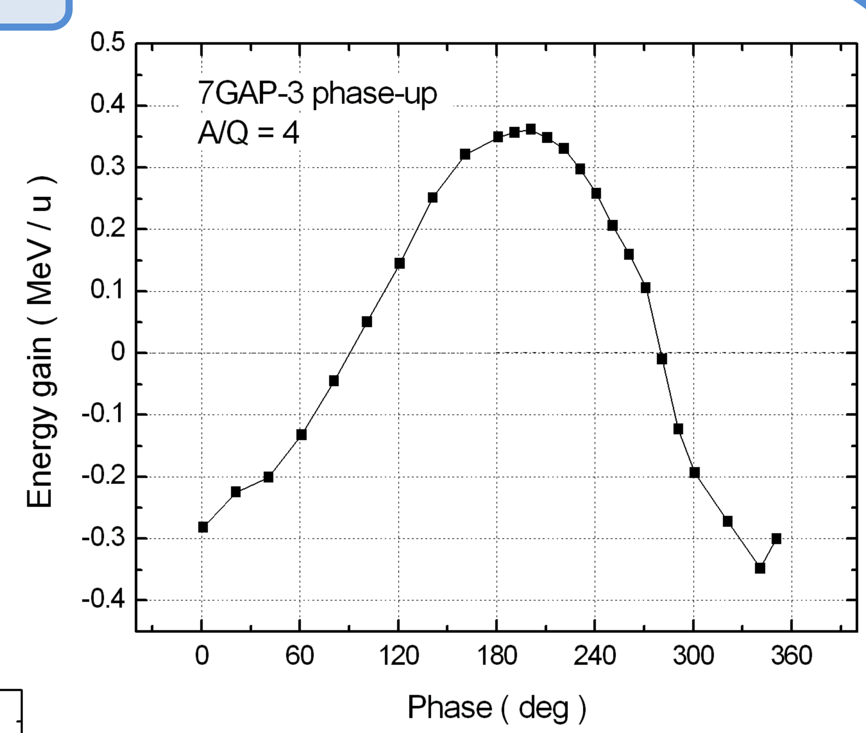


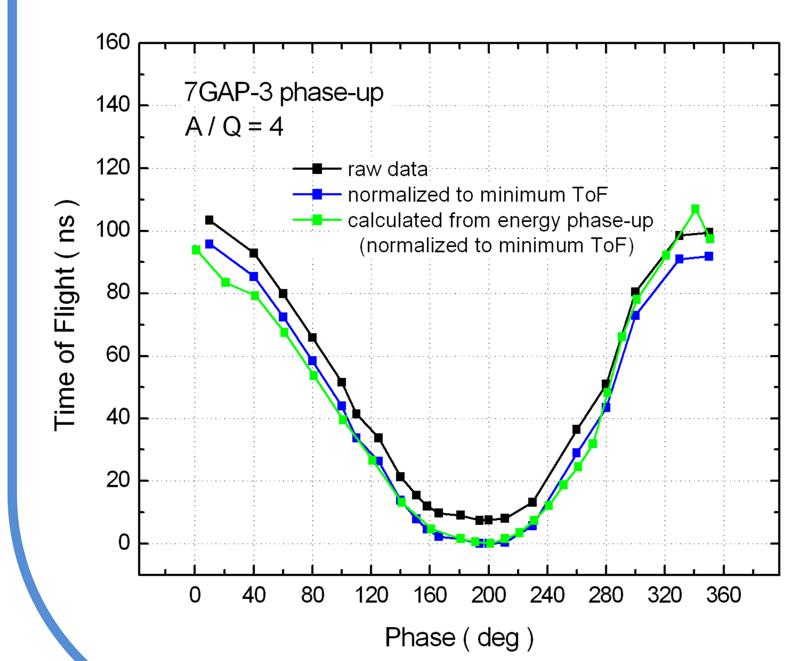
REFERENCE SIGNAL RESOLUTION



Cavity Phase-up

The **principle of cavity phase scanning** has been successfully demonstrated for the 7GP3 cavity by means of the energy measurements, as the main purpose of the silicon profile monitor. While varying the cavity phase, the energy peak position is quickly recorded and plotted in terms of energy gain.





A cavity phase-up procedure has also been tested with a Time-of-Flight (TOF) measurement. Unfortunately, in the tested experimental condition, i.e. with a 10 m distance between the cavity and the monitor, and in the absence of a beam chopper, a large number of data points are required to reconstruct the phase curve, which slows down the whole procedure. The bunch's movement across the 9.87 ns window has in fact to be followed in order to add the correct number of bunch periods to the ToF measurement.